UCRL-JC-135621 Abs

Ultrasonic Velocities in Unconsolidated Sand/Clay Mixtures at Low Pressures

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Effective seismic interrogation of the near subsurface requires that measured parameters, such as compressional and shear velocities and attenuation, be related to important soil properties. Porosity, composition (clay content), fluid content and type are of particular interest. The ultrasonic (100-500 kHz) pulse transmission technique was used to collect data for highly attenuating materials appropriate to the vadose zone. Up to several meters of overburden was simulated by applying low uniaxial stress of 0.1 MPa to the sample. The approach was to make baseline measurements for pure quartz sand, because the elastic properties are relatively well known except at the lowest pressures. Clay was added to modify the sample microstructure and ultrasonic measurements were made to characterize the effect of the admixed second phase. Samples were fabricated from Ottawa sand mixed with a swelling clay (Wyoming bentonite). The amount of clay added was 1 to 40 percent by mass. Compressional (P) velocities are low, ranging from 169 to 450 m/s for the mixtures at low stress. Shear (S) velocities are about half of the compressional velocity, but show different sensitivity to microstructure. Adding clay increases the shear amplitude dramatically with respect to P, and also changes the sensitivity of the velocities to load. These data are available at www-ep.es.llnl.gov/www-ep/esd/expgeoph/Berge/EMSP/. These experiments demonstrate that P and S velocities are sensitive to the amount of clay added, even at low concentrations. Other properties of the transmitted signals which include the ratio of S and P amplitudes, velocity gradient with depth, and the frequency content of transmitted pulses, provide additional information about the clay content. Direct observation of sand-clay microstructure indicated that the clay particles electrostatically cling to the sand grains but do not form a coating. Instead, in the dry mixture clay particles tended to bridge the gaps between grains, influencing how stresses were carried across grain contacts. Because of this tendency to bridge the gaps, small amounts of clay can have large effects on the wave propagation.

Acknowledgements
We thank B. Viani for advice on the selection and properties of smectites. This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48 and supported specifically by the Environmental Management Science Program of the Office of Environmental Management and the Office of Energy Research.